RISK MANAGEMENT IN CONSTRUCTION PROJECTS USING STATISTICAL MODELLING

A SYNOPSIS

Submitted by

J. SENTHIL

(Reg. No. 201805241)

in partial fulfillment for the award of the degreeof

DOCTOR OF PHILOSOPHY

DEPARTMENT OF CIVIL ENGINEERING

SCHOOL OF MECHANICAL AERO AUTO AND CIVIL ENGINEERING

KALASALINGAM ACADEMY OF RESEARCH AND EDUCATION

(DEEMED TO BE UNIVERSITY)

ANAND NAGAR, KRISHNANKOIL - 626 126

TAMIL NADU, INDIA

SEPTEMBER-2023

1. INTRODUCTION

Risk management in construction projects has been acknowledged as a crucial management procedure for achieving the project's cost, schedule, quality, safety, and environmental sustainability goals. However, most research has concentrated on certain areas of construction risk management rather than utilizing a systematic and comprehensive strategy to identify risks and estimate the likelihood of their occurrence and potential consequences. The Construction Project has innumerable risks that impact the entire project life cycle, affecting time overruns and costs due to improper Risk Management throughout the Project Lifecycle. Risk factors are identified, and uncertainties are quantified [1]. Every area has numerous risks, but the risk rate is higher before and after construction. The risks in certain areas may be the same, but the impact and probability may differ. It would lead to an overrun of time and cost and sometimes project failure.

ISO/IEC Guide 73 defines risk management as applying management rules, procedures, and practices to communicating, consulting, establishing the context, identifying, analyzing, assessing, treating, monitoring, and reviewing risk [2]. Identify and manage enterprise-wide risks that may be roughly categorized into four risk categories: strategic, operational & cultural, financial, and hazard risks [3]. Construction project risk management has been the focus of extensive research and development in recent years. It is commonly acknowledged as one of project management's most important approaches and skill sets [4]. Failures in construction risk management are typically depicted as catastrophic structural collapses or tragic occurrences. However, project risk management extends beyond the safety of people and buildings. International Organization for Standardization (2003) [5] defines a project as "a unique process consisting of a sequence of coordinated and controlled operations with start and end dates, conducted to accomplish a defined goal within the constraints of time, money, and resources." Project Risk Management (PRM) reduces the probability of failing to accomplish the project's objective to an acceptable level. It sought to maximise the good consequences of opportunities while minimising or eliminating the negative repercussions of risk occurrences.

Considering the necessity aspect of risk, it is required to anticipate risk so the project may avoid it and achieve successful completion. This dissertation proposes six distinct risk management models that function by forecasting potential dangers. The project avoids complications as the risks are anticipated prior to their manifestation. In addition, risks may be efficiently handled when their occurrence probability is calculated. This work uses neural networks to forecast risk. The initial phase of research work presents a risk management scheme that mainly focuses on risk factors. The second phase of research studies the statistical risk management in the construction industry, and the third phase presents a risk management model

based on Modified Historical Simulation Statistical (MHSS) methods. Different risks such as climate, design, inflation, resource and other uncertain events are also considered in this work. The fourth phase of work presents a MHSS-ANN model based on enhanced neural networks. The fifth phase of work presents Deep Recurrent Neural Network (DRNN) for a statistical risk management scheme based on the Modified Sine Cosine Optimization Algorithm (MSCA) in the fifth phase. The final phase of the research proposes a Particle Swarm Optimization (PSO) algorithm based on Deep Reinforcement Learning (DRL) for risk prediction. The performances of all the proposed approaches are evaluated and compared against existing approaches. The experimental outcomes prove that the proposed works perform better due to the optimized exploitation of artificial intelligence in risk prediction.

2. LITERATURE REVIEW

The risk management idea is an exceedingly uncommon strategy in the construction business, whereas a systematic risk approach is being developed to deal with the risk associated with meeting the project's scope and characteristics. This research presents a strong and decisive risk method for identifying and managing Construction project risks. This studies and discusses the overall concept of risk and its management. The related works are then discussed in the following section.

1. Risk Concepts
2. Risk Factors Affecting the Project
3. Risk Statistical Model
4. Prediction and analyses of Value at Risk

2.1. RISK CONCEPTS

Risk indicates the likelihood of an event or circumstance resulting in adverse consequences for individuals, systems or resources. A risk may be defined as an unpredictable occurrence or circumstance that, in the event of its realisation, will result in either a detrimental or advantageous impact on one or multiple project goals. Several risk factors contribute to subpar project performances, leading to frequent schedule delays, exceeding budgetary limits, compromising quality and resolving disputes and conflicts within the industry [6]. Numerous obstacles have been encountered in project management, including project risk and uncertainty, unpredictability in project results, task fragmentation, complex relationships among stakeholders and activities, and excessive overlaps among project phases. Construction risks can be classified to many factors, including the source of the risk, the potential impact and stage of the project [7].

Risk management is an effective strategy for mitigating and eliminating risks within Construction projects. Most of the risk management is implemented after identifying risks,

ensuring that the project is executed within the predetermined timeframe and budget while upholding the desired level of quality as expected by both the client and contractors [8]. Operational risks include a range of factors, including unplanned demand, limited product life, rapid product turnover and seasonal fluctuations [9]. Establishing a correlation between risk and operational contingencies necessitates an examination of several factors, including natural catastrophes, such as earthquakes, hurricanes, and storms, as well as instances of terrorism and political instability [10], in addition to both natural and anthropogenic calamities. Catastrophic events are identified as the primary source of risk [11]. The risk categories that may be identified are interruptions, delays, systems, forecast, intellectual property, procurement, receivables, inventory and capacity [12].

In the literature review, the term "risk" pertains to the possibility of uncertain or unpredictable events or circumstances affecting the projects. The concepts related to risk serve as a fundamental basis for comprehending and effectively handling risks, enabling individuals and organisations to make well-informed decisions and safeguard themselves against potential adverse consequences. The underlying rationale is that implementing risk management practices can enhance the ability to effectively oversee projects in terms of time and cost management. Integrating a greater number of risk management strategies, including the grouping and establishment of appropriate relationships, significantly impacts project outcomes. However, it is essential to note that there is a lack of flawless programmes and systems that can accurately calculate the extent and severity of risk occurrences.

2.2. RISK FACTORS AFFECTING THE PROJECT

Risk factors have a significant influence on the main objectives of construction projects. Construction projects are complex, including several sources of uncertainty and associated risks. Risk management is a systematic approach that involves the identification, qualitative and quantitative analysis, response planning, and ongoing monitoring and control of risks. No projects are free from risk. The factors affecting the risks are in higher percentage nowadays. The objective of the construction projects keeps changing, but during the implementation, the objective may change according to the current stage of the project.

The risk factors impacting variables provide concrete evidence for the occurrence of time overruns observed throughout the study. Cost-reimbursable contracts may be defined as contractual arrangements that include the estimated value of the activities to be performed and the corresponding costs related to any changes made to the initial project scope [13]. The construction project has a plethora of significant risks and uncertainties that are intrinsic to international construction undertakings. The process of identifying and evaluating potential risks should be

undertaken at the first bidding phase of a Construction project [14]. The implementation of a proactive strategy is of utmost importance in the mitigation of risks, as well as in the reduction of the probability of experiencing schedule and expenditure overruns [15]. The identified high-impact risks in a construction project include inadequate and deficient planning, inadequate safety measures on site, insufficient coordination among employees, limited availability of resources, and substandard quality of materials. All of these risks are carefully considered and mitigated in order to ensure the effective execution of a construction project [16]. Identifying major risks was prioritised from the construction project successfully attaining the desired objectives in terms of time, money, and quality. A total of 111 dangers were considered, with about 56 being identified as the most significant risk variables and given more emphasis. Risk perception has evolved from being primarily based on estimate variance to being influenced by project features. However, the persistent belief in the potential for a significant effect in high-risk situations led to several instances of failure and increased dangers inside the Construction project [17].

Based on the aforementioned literature review, it is found that there exists a comprehensive range of over 140 risk factors that have an impact on construction projects. Additionally, the review identified 40 significant factors that consistently influence construction projects, affecting them repeatedly. Risk factors play a crucial role in developing appropriate risk mitigation strategies, efficient resource allocation, and establishing contingency plans to minimise the potential impact of risks on the project. This paper examines the impact of risk on project evaluation within the construction industry and the various tools and methodologies employed to effectively mitigate risk.

2.3. RISK STATISTICAL MODEL

The state-of-the-art in construction simulation. To solve quantitative research based on the numbers is called simulation. The simulation technique is used in the construction industry to solve the risks involved in a construction project. There are various kinds of simulation techniques like modular, Monte Carlo, agent-based modulation & simulation, risk analysis, etc. The major risks from the kinds of literature were found, and the specialized simulation approaches were applied in the construction project. Hence, proper simulation technique is used for each project; not all types of simulation are used in industry. There are lots of modelling techniques to solve the risks involved in project, though here, the study uses the statistical simulation approach method to reduce risks and predict the exact time to complete the project.

The risk management probability was investigated by Krishnakant Upadhyaya and Mallik (2013) using the Socio-Technical Systems Approach. One advantage of using risk hierarchies for decision-making is the ability to prioritise risks. However, a potential drawback of

this approach is the reduction in the quantity of project risk management performance measures [18]. Hamzaoui et al. (2019) used the MADS and MOSAR methodologies to efficiently identify and mitigate risk failures. However, it is important to note that their research findings exhibit some limitations. Neglecting the safety barrier is the underlying factor contributing to the disparity in cost, time, and quality percentages [19]. Tsung-Chieh Tsai (2009) used the Pareto Diagram for two-dimensional evaluation to assess the risk created and the advantage in Value at Risk. One notable discrepancy in the field of risk assessment and risk categorization is the absence of a consistent risk value, leading to incongruities across different projects [20]. Indrajit Roy (2011) used Historical Simulation to determine Values at Risk (VaR). This methodology's advantage is its ability to determine Value at Risk (VaR) using historical data. Notably, this particular approach is mostly used within banking, insurance, and the broader stock market [21].

The preceding literature review indicates that the risk statistical model uses statistical methods and techniques to quantitatively evaluate and analyze risk. The preceding section provides a comprehensive literature review for using historical simulation and offers several advantages, such as its straightforwardness, straightforward implementation, and reliance on authentic historical data. However, it is important to note that this approach is mostly used in the financial sector. The historical simulation approach necessitates modification and customization to adapt to the specific requirements of construction projects in order to ascertain the time value at risk.

2.4. PREDICTION AND ANALYSES OF VALUE AT RISK

The prediction of Value at Risk gives the opportunity to accomplish a successful project. To control all risks involved in construction, the risks should be identified, assessed, controlled, and provided with a proper solution. The risks in certain areas may be the same, but the impact and probability may differ. It would lead to time overrun, cost deficit and sometimes project failure. Mahmoudi et al. (2020) [22] developed an innovative risk management approach that employs three distinct methodologies: the Best Worst (BW) approach, Grey Relation (GR) analysis, and the Analytic Hierarchy (AH) process, to effectively minimize risks. Score, rank, differentiating coefficient, and grey connection grade were utilised as performance metrics in this method. This approach failed to define significant factors in identifying construction project risk. Zhang et al. (2020) [23] demonstrated Occupational Health and Safety in green building construction projects through a Holistic Z-numbers-based Risk Management (HZRMS) approach. The performance metrics employed in this approach are Magnitude, risk weight, safety risk, rank and frequency. This approach involves identifying the critical safety risk during the construction of projects, but the implementation is complex. A critical success factor (CSF) framework for

effective implementation of risk management was proposed by Qammaz et al. (2020) [24]. Rank, cluster, and time were used as assessment criteria in this method. This method has less construction risk but is less effective. Enshassi et al. (2019) [25] designed an integrated risk management system to facilitate tolerance-based mitigation strategy decision-making for modular building projects. In this method, performances are assessed based on coefficient value, risk impact and input percentile. The experimental results were completed, and the analysis demonstrated that this method provided improved modularization performance at the expense of precision.

Chatterjee et al. (2018)[26] suggested a hybrid MCDM approach for construction project risk management. Three different types of risk are employed in this approach, namely external risk, internal risk and project risk. The experimental study was performed, and the results indicate that this method has a high sensitivity and reliability value but could not identify the concealed risk. Mhetre et al. (2016) [27] established an effective risk management system using work breakdown structure (WBS) and risk breakdown structure (RBS). Rank and weighted score are the performance indicators utilised by this method. This solution was offered with a low-risk value, but its implementation appears difficult. Wang et al. (2018) [28] established a risk evaluation and control strategy for industrialised Construction projects based on meta-networks. Risk factors, cost, duration and likelihood rate were utilised as performance indicators for this method. The investigation found that this strategy has a high rate of practicability. But, the system's efficacy is relatively low.

Improving accuracy is an iterative process that may require multiple iterations of experimentation, evaluation, and refinement. The exploration capabilities of the Deep Recurrent Neural Network and Modified Sine Cosine Algorithm (DRNN & MSCA) algorithm enhance convergence speed and the accuracy value's quality. Based on the aforementioned literature review, it is suggested that the utilisation of Particle Swarm Optimised Deep Reinforcement Learning (POS &DRL) can enhance performance and expedite convergence in complex reinforcement learning tasks.

3. Motivation of research

Construction Risk Management arises from recognising that the construction industry is inherently complex and uncertain. This field involves numerous stakeholders, intricate processes, and significant investments, making it susceptible to various risks that can impact project success. Most of the project uses the Probability Assumption Percentage, which does not give the correct result of the forecast project Time. The project outcome is delivered in a highly complex network. Still, research on how project risk management should be adapted to the

network environment is scarce. Hence, this study uses a scientific approach to assess the Value at Risk Time.

3.1. Aim

This research aims to evaluate the possibility of time overruns in construction projects, implement successful project-management strategies to mitigate these risks and accurately determine the actual duration of the construction projects.

3.2. RESEARCH OBJECTIVES

The research objectives are,

1. To classify the various risk factors in construction projects and to evaluate the impact of the risk factors in the project.
2. To estimate the uncertainty risk impact due to risk factors in a similar construction project and determine the risk effect.
3. To develop a model based on the impact of the risk factor in effect and forecast to minimise the risk impact in the project.
4. To minimise the error in the developed model by using ANN technique and validating the model to prevent the impact of the risk.
5. To predict and forecast the risk factors in the construction project with the real-time project of projection completion of time and indirect cost.

4. STUDY METHODOLOGY

Following a comprehensive review of the relevant literature, the methodology applied to this study consists of five main components. These components include i) Data collection from Historical Project data and Construction Project Risk survey; ii) Risk factors influencing project analysis; iii) The Risk Statistical Model; iv) The prediction and analysis of Value at Risk (VaR) over time; v) The formulation of risk associated with time overruns. Utilising the established model, the forecasted Time Value at Risk (TVaR) is determined for future and current scenarios. Figure 4.1 presents the overarching flowchart of the research study, encompassing a thorough investigation in which a detailed analysis was conducted, and the resulting outcomes were meticulously documented. The parameter influencing TVaR is the probability of the possibility of project completion duration.

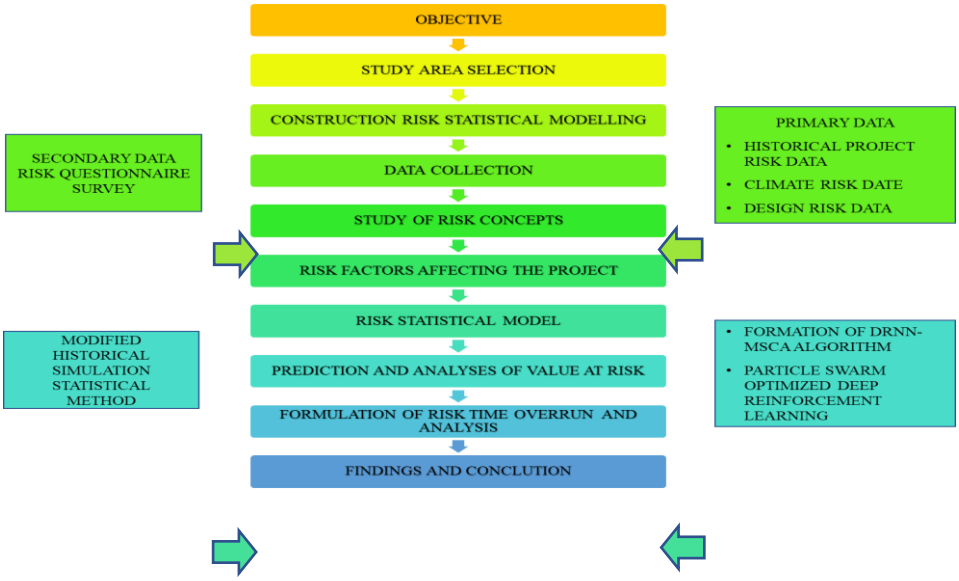


Fig 4.1. Flow chart of the research

5. MODEL DEVELOPMENT AND VALIDATION

Historical simulation techniques are frequently used in the banking and financial sectors. However, it is not feasible to directly apply the same methodology to construction projects. Therefore, modifications are necessary to adapt historical simulation for use in the construction industry. There are different elements in construction projects, with time being an essential consideration. Therefore, creating a modified historical simulation method specifically designed to predict the Time Value at Risk (TVaR) in construction projects is essential. Fig 5.1, the subsequent section, outlines the execution procedure involved in constructing the Modified Historical Simulation Method (MHSS). The values of risk factors are determined through a modified historical simulation technique for the four main risk modules, namely Climate, Design, Financial, and Resource, as well as the Typical Uncertain Event module for comparable projects.

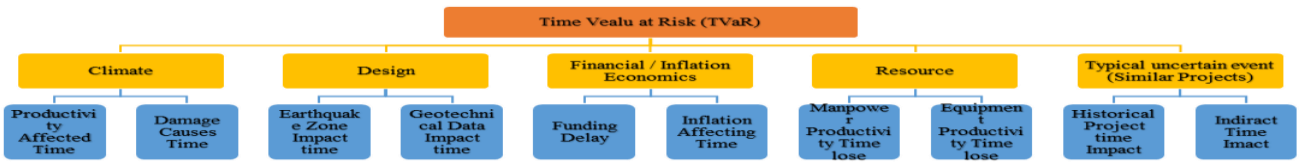


Fig.5.1 TVaR

5.1. Climatical Risk Factor Model

The current model aims to determine the Climate Risk Factor, which is obtained from forecasts based on historical data. This factor encompasses known and unexpected risks, with the key elements impacting it being the number of rain days and crop production. Equation 5.1 presents the model for determining the climatic risk factor.

$$\text{Climate Risk Factor } CRF = \frac{\sum_{n=0}^{n}(RD_{cn} + AD_{cn}))}{PD} \quad (5.1)$$

Where, CRF is the Climate Risk Factor, RD_{cn} Rain days, AD_{cn} Affected days by climate, PD Project duration, cn Number of Climate window analyses, n Number of iteration.

5.2. Design Risk Factor Model

The Design and Built construction project have a substantial impact on the risk associated with design, particularly in terms of project duration and cost. Also, it will influence three key risk variables, particularly the geotechnical information specific to an earthquake-prone location and the present climatic conditions. Equation 5.2 presents the model for determining the Design risk factor.

$$\text{Design Risk Factor } DRF = \frac{\sum_{n=0}^{n}(DD_{dn} + AD_{dn})}{PD} \quad (5.2)$$

Where, DRF is the Design Risk Factor, DD_{dn} Number of impact due to design , AD_{dn} Affected days by design, PD Project duration, dn Number of Design window analyses, n Number of iteration.

5.3. Resource Risk Factor Model

The project's execution phase could encounter delays due to a lack of skilled labourers, such as engineers, contractors, and planning engineers. The temporary cessation of construction due to a scarcity of unskilled labour, including painters, electricians, tile workers, and masons, would increase the project's associated risks. Equation 5.3 presents the model for determining the Resource Risk Factor.

$$\text{Resource Risk Factor } RRF = \frac{\sum_{n=0}^{n}(RM_{rn} + AD_{rn})}{PD} \quad (5.3)$$

Where, RRF is the Resource Risk Factor, RM_{rn} Number of days impacted due to resources, AD_{rn} Affected days by resource, PD Project duration, rn Number of resources window analyses, n Number of iteration.

5.4. Financial Risk Factor Model

This is one of the most significant risks in the construction industry, and it directly impacts the project's budget. Inflation raises the prices of construction raw materials, labour, and construction equipment machinery, negatively influencing the original budget time and cost. Equation 5.4 depicts the model for calculating the Financial Risk Factors.

$$\text{Financial Risk Factor } FRF = \frac{\sum_{n=0}^{n}(FR_{fn} + AD_{fn})}{PD} \quad (5.4)$$

Where, FRF is the Financial Risk Factor, FR_{fn} Number of days Impacted due to Financial, AD_{fn} Affected days by finiancial, PD Project duration, fn Number of financial window analyses, n Number of iteration.

5.5. Typical Uncertain Risk (Similar Projects)

Uncertainty Risks are there in every project, particularly in construction, and most of the risks are repeatedly occurring, but the impact and probability of risk vary. This model will capture the recurring historical baseline uncertainty upon which the risk-based model was constructed. Equation 5.5 depicts the model for calculating the Uncertainty Risk Factor.

$$\text{Uncertainty Risk Factor } URF = \frac{(\sum_{n=0}^{n+1}(RR))}{UVaR} \quad (5.5)$$

Where,URF is the Uncertinty Risk Factor, RR Risk rating, UVaR Uncertinty Value at risk

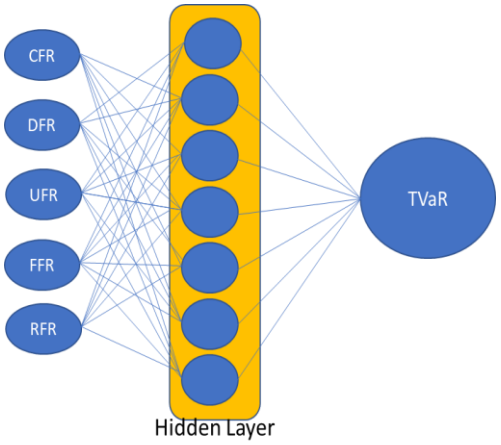
5.6. Modified Historical Simulation Method

The historical simulation approach is the most often used method for estimating VaR in the financial and stock market industries. Due to the many risks that affect the project, the same strategy cannot be used in the construction industry. As a result, this strategy has been adjusted to meet the construction schedule. The five key risk variables impacting time overrun are climate, design, financial, resource, and uncertainty risks. The model for computing the Time Value at Risk is shown in Equation 5.6.

$$\text{Time Value at Risk } TVaR = \frac{(PD_n \times (\sum_{n=0}^{n}(CRF+DRF+FRF+RRF+URF)_n))}{PDex} \quad (5.6)$$

Equation (5.6) presents the Time Value at Risk (TVaR) formula, incorporating variables like project duration (PD), expected project duration (PDex), and various risk factors, including Climate Risk (CRF), Design Risk (DRF), Resource Risk (RRF), Financial Risk (FRF), and Uncertainty Risk (URF). Following the definition of maximum iterations and initial population setup, the model requires the collection of Historical Risk data spanning different scenarios, sizes, and risk types. This data informs the classification of climate, design, financial, resource, and typical uncertainty risks. By listing potential hazards within these categories, the Time and Cost Value at Risk is calculated using the Modified Historical Simulation Method, providing insights into project vulnerabilities in both time and cost domains.

Figure 5.1 illustrates the schematic representation of the Artificial Neural Network (ANN) model employed in this research. To evaluate the accuracy of the Modified Historical Simulation Spatial (MHSS) models, a least square fitting method was utilized for validation. The actual and predicted values were compared using MHSS spatial layers in conjunction with the ANN, as depicted in Figure 5.2. Similarly, the Deep Recurrent Neural Network and Modified Sine Cosine Algorithm (DRNN & MSCA) approach's outcomes are shown in Figure 5.3, while Particle Swarm Optimized Deep Reinforcement Learning (PSO-DRL) results are presented in Figure 5.4.



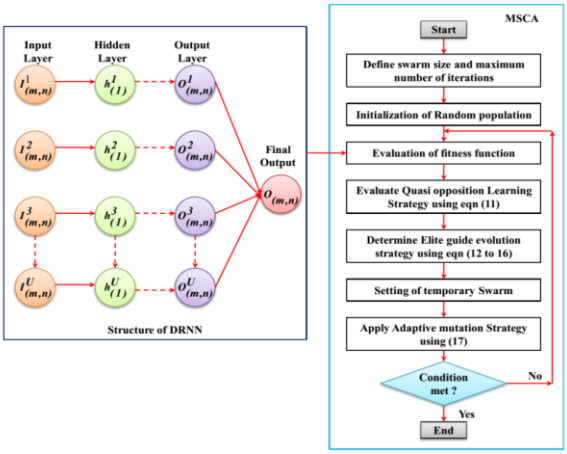


Fig.5.2 FMHSS- ANN **Fig.5.3MHSS- DRNN-MSCA**

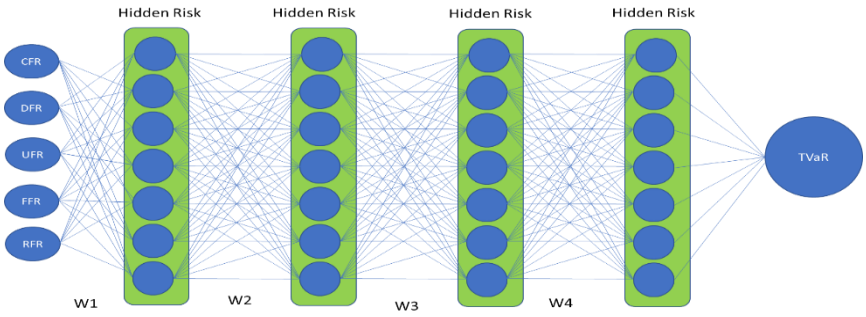


Fig.5.4 MHSS- PSO-DRL

Compared to the MHSS and PSO-DRL Algorithm models, it performs better and predicts results than the MHSS model. However, the results show that models are appropriate for predicting TVaR values.

6. RESULT ANALYSIS AND DISCUSSION

A study was conducted to assess the impact of risk on time overruns in construction projects. A dataset of 8000 data points was collected from 112 projects and analysed in a statistical mathematical model proposed to calculate the Value at Risk (VaR) for a given time in a construction project. The time overrun of a construction project has significant implications, as it introduces risks that can be addressed through a mathematical innovation aimed at identifying and reducing project duration.

6.1. Climate Risk Factor

The climate in India varies from state to state, with the yearly number of rainy days ranging from 10 to 130 days on average, affecting the construction schedule by 20% to 41%. Temperature verification for winter and summer also affects project productivity, which will be reflected in time overrun. The climatic risk factors considerably impact the duration of completed projects computed using the 5.1 model.

6.2. Design Risk Factor

The design of a construction project has a significant impact on both the duration as well as the price of the project. Furthermore, it will influence three important aspects: geotechnical information for an earthquake-prone location and prevailing climatic conditions. The time overrun caused by design impacts, in the ranging from 1% to 4%. The calculations were performed using the 5.2 model.

6.3. Resource Risk (Manpower & Equipment)

The accessibility of construction resources exhibits variability contingent on project type and geographical location. Certain regions encounter constraints in resource availability, compelling construction enterprises to source materials from neighboring regions or even foreign countries. Likewise, the presence of equipment displays notable disparities across projects and geographical areas. Resource Risk Factors were factored into the analysis, with an estimated range spanning 5% to 10%. These calculations were executed utilizing the 5.3 model.

6.4. Financial /Inflation Economics Risk

Inflation Economic is highly reliant on a nation's GDP and the value of its currency; it influences the pricing of construction raw materials, construction equipment, labor expenses, and the country's overall economy. The Consumer Price Index (CPI) and the Wholesale Price Index (WPI) can be used to measure this risk factor from 2% to 6%. The computations were conducted using the 5.4 model.

6.5. Typical Uncertain Risk (Similar Projects)

The construction industry is very at risk-to-risk concerns. In most cases, risks are overlooked, resulting in the project's failure. This was selected to identify and remove risks at their source and complete the project within the schedule and budget constraints. India is the country examined in this study. Around 20 important uncertain risk factors have been categorised as low risk, medium risk, or high risk. The 5.5 model was used to compute the Uncertain Risk factor, which ranged from 7% to 21%.

6.6. Modified Historical Simulation Statistical Methods (MHSS)

The project data collected and applied the Modified Historical Simulation Statistical Methods, we evaluated the Time Value at Risk (TVaR) from each Project date and compared the Predicted value with the Actual value shown in Fig 6.1.

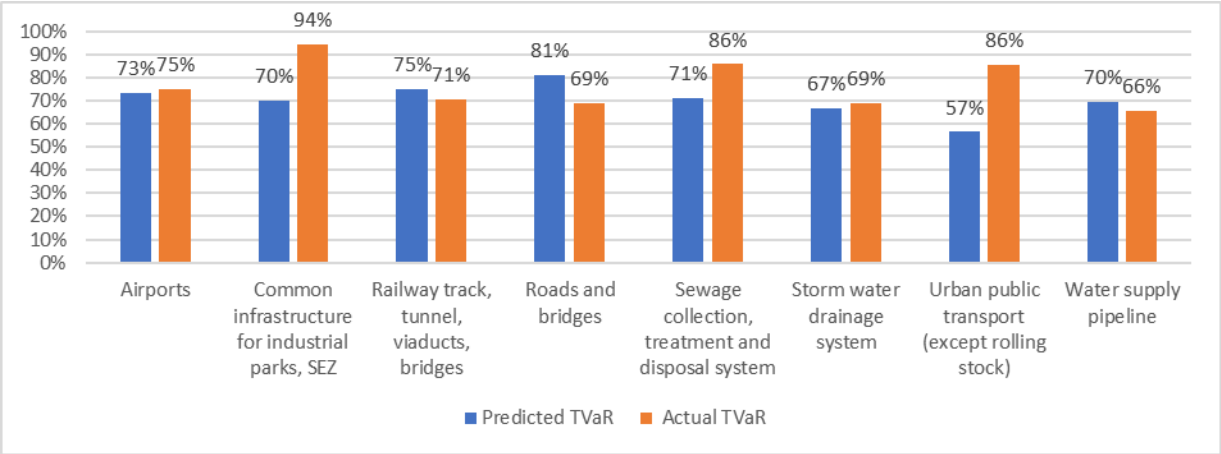


Fig 6.1 MHSS-Predicted TVaR vs Actual TVaR

The Predicted TVaR and Actual TVaR results were compared and evaluated in the percentage error. The resulting accuracy is 65%, shown in Table 6.1.

Mean Absolute Deviation	Mean squared error	Mean absolute percentage error	Root Mean squared error
20%	7%	35%	26%

Table 6.1 MHSS percentage error.

6.7. MHSS-ANN Time Value at Risk (TVaR)

Using the Modified Historical Simulation Statistical Methods and ANN, the researcher evaluated the Time Value at Risk (TVaR) from each project date and compared the Predicted value with the Actual value, as shown in Fig 6.2.

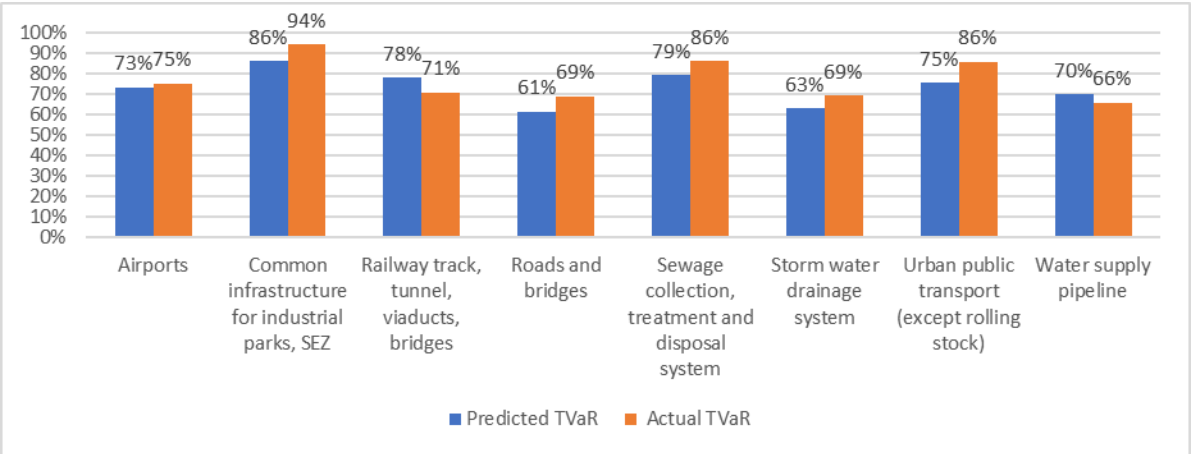


Fig 6.2 MHSS-ANN-Predicted TVaR vs Actual TVaR

Mean Absolute Deviation	Mean squared error	Mean absolute percentage error	Root Mean squared error
18%	5%	28%	23%

Table 6.2 MHSS -ANN percentage error.

The Predicted TVaR and Actual TVaR results were compared and evaluated in the percentage error. The resulting accuracy is 72%, shown in Table 6.2.

6.8. MHSS- DRNN-MSCA Time Value at Risk (TVaR)

By utilizing the Modified Historical Simulation Statistical Methods - DRNN-MSCA, the researcher assessed the Time Value at Risk (TVaR) for each project date. This evaluation included comparing the Predicted and corresponding Actual values, as illustrated in Figure 6.3.

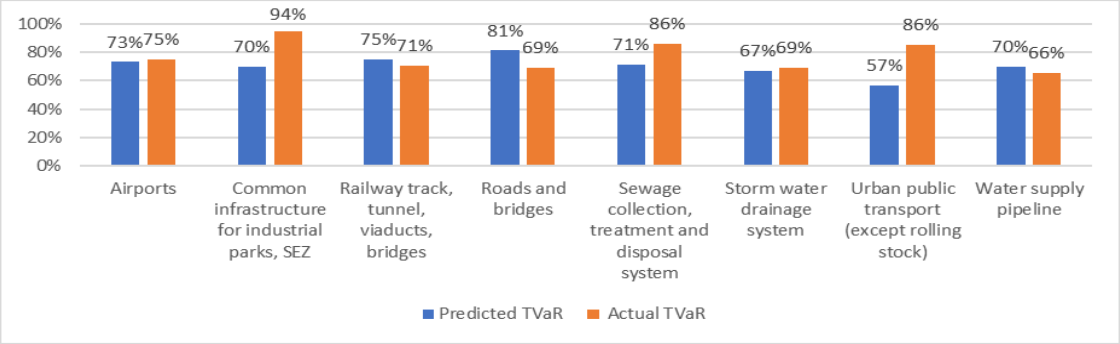


Fig 6.3 MHSS-DRNN-MSCA Predicted TVaR vs Actual TVaR

Mean Absolute Deviation	Mean squared error	Mean absolute percentage error	Root Mean squared error
15.1%	3.7%	18.6%	19.3%

Table 6.3 MHSS-DRNN-MSCA percentage error

The Predicted TVaR and Actual TVaR results were compared and evaluated in the percentage error. The resulting accuracy is 81.4%, shown in Table 6.3.

6.9. MHSS-PSO-DRL Time Value at Risk (TVaR)

Through the Modified Historical Simulation Statistical Methods - PSO-DRL application, the researcher evaluated the Time Value at Risk (TVaR) for every project date. This assessment encompassed a comparison between the Predicted and corresponding Actual values, visually represented in Figure 6.4.

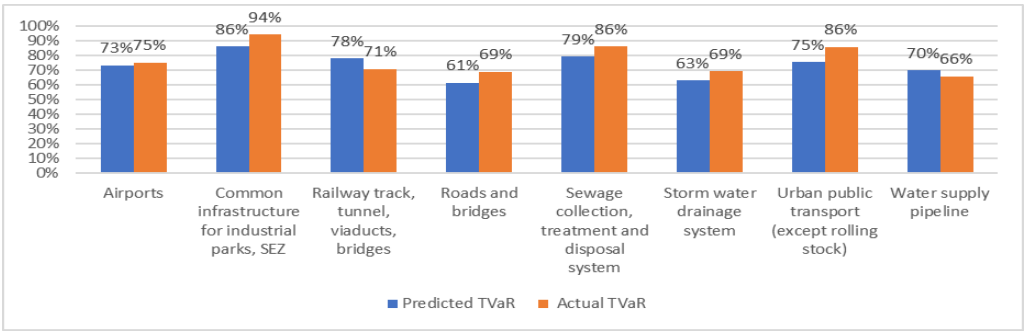


Fig 6.4 MHSS- PSO-DRL Predicted TVaR vs Actual TVaR

Mean Absolute Deviation	Mean squared error	Mean absolute percentage error	Root Mean squared error
8.8%	**1.3%**	**10.9%**	**11.3%**

Table 6.4 MHSS- PSO-DRL percentage error

The Predicted TVaR and Actual TVaR results were compared and evaluated in the percentage error. The resulting accuracy is 90.1%, as shown in Table 6.4.

7. Conclusion

Risk management is a proactive project management strategy that reduces a course of action's susceptibility to losses and leaves an auditable trail of modifications. Risk identification and prioritising the key and risk activities that have the biggest effect on the project lifecycle to reduce the time overrun. 8000 data points were collected from 112 projects and evaluated to determine the influence of risk on Time overruns in the Project construction lifecycle. The risk data used for analysis and interpretation in this study was collected from many infrastructure projects. There were 40 significant risk factors identified in relation to the impact of the Construction Project for Time overrun. A total of 40 risk factors fall into the category of large groups, specifically categorised as category 5 major groups, and it leads the Time overrun by 80%, resulting in significant risks related to the climate, design, resources, finances, and uncertainty.

The impact of risk variables on construction projects ranges from 20% to 41% for climatic risk, 1% to 4% for design risk, 5% to 10% for resources risk, 2% to 6% for financial risk, and 7% to 21% for uncertainty risk. As the Indian climate varies from state to state, the construction schedule is affected. Hence, the historical information on climate helps in the risk analysis of climate and its impact over time and cost. Modified Historical Simulation Statistical Methods (MHSS) and established an effective and accurate risk prediction, including climate, design, inflation of economics, resource (Manpower and equipment) and other typical uncertain events. The result of the MHSS Model predicted time overruns and compares the actual project duration completion produced in MAPE is 35%, as shown in Table 6.1.

MHSS-Artificial Neural Networks (ANN) are algorithms based on brain function. They are used to model complicated patterns, forecast the construction delay's interdependence and complexity, predict time overruns, and compare the actual project completion time in MAPE, which is 28%, as shown in Table 6.2. A machine learning algorithm, namely the Deep Recurrent Neural Network (DRNN) and the Modified Sine Cosine Optimisation Algorithm (MSCA), is integrated to minimise the interdependence and complexity of the construction delay, predicted time overruns and compare the actual project completion time in MAPE is 18.8% shown in Table

6.3. The Particle Swarm Optimised Deep Reinforcement Learning machine learning algorithm projected time overruns and compared them to the actual project completion time in MAPE, which is 10.9% shown in Table 6.4. The MHSS-PSODRL is applied in the live project, and the obtained results were evaluated for accuracy, with a range of 92.01% to 94.98%, as shown in Table 7.1

S.No	Project Name	Duration in days	Actual Duration in days	Time Overrun		Accuracy (%)
				Actual in days	MHSS-PSO-DRL in days	
1	MTHL–Package-1	1642	2012	370	351.4	94.98%
2	MTHL–Package-2	1642	2012	370	348	93.99%
3	MTHL–Package-3	1095	1514	419	386	92.01%

Table -7.1 Live Project Predicted Duration and Actual Duration

Most projects are affected by risks, such as climate, design, resources and typical uncertain events. The risk data is obtained from various infra projects for analysis and interpretation with risk factors to calculate the time and cost of risk for mitigation. The analysis of the performances of all proposed approaches demonstrates their effectiveness compared to existing works, as supported by experimental results.

8. ORGANIZATION OF THESIS

The thesis has been categorized into six chapters

Chapter 1: Introduction

This chapter delves into an introduction to the concept of risks, exploring a range of constraints and potential risks inherent in the risk management domain. It encompasses an in-depth examination of historical simulation analysis and outlines the comprehensive scope and primary objectives of the research endeavor.

Chapter 2: Review of literature

This chapter presents key components of the literature review pertaining to studies in risk management. It delves into the historical simulation method as an approach for risk assessment and also includes discussions on the various risk factors.

Chapter 3: Research Methodology

This chapter outlines the research methodology employed in the proposed work. It elucidates the research process's overarching flow and the approach to data collection centred around Construction Project Risk data. The chapter details major risk categories within this

context, including Climate Risk, Design Risk, Inflation Economics Risk, Resource Risk (encompassing both Manpower and Equipment considerations), and typical uncertain events associated with similar projects.

Chapter 4: Prediction analysis of Time overrun.

This chapter explains the model based on the impact of the risk factor in effect and forecasts to minimise the risk impact on the project. The prediction and analysis of the Value at risk Time using MHSS and ANN- Algorithm approach have also been discussed.

Chapter 5: Result and Discussion

This chapter describes the result and discussion of the research work carried out.

Chapter 6: Conclusion

This chapter reveals the overall conclusion of the research work.

9. REFERENCES

1. S. M. Renuka, C. Umarani and S. Kamal "A Review on Critical Risk Factors in the Life Cycle of Construction Projects" Journal of Civil Engineering Research 2014, 4(2A): 31-36
2. ISO/IEC Guide 73 (2002) Risk management – vocabulary – guidelines for use in standards. International Organization for Standardization, Geneva
3. Casualty Actuarial Society (CAS). (2003). Overview of Enterprise Risk Management. Retrieved from
4. Klemetti, A. (2006). Risk management in construction project networks. Helsinki University of Technology, Finland.
5. Geneva, S. (2003). International Organization for Standardization; 2005. International Organization for Standardization ISO Standard, 4049, 1-4.
6. K T Yeo and J H Ning (2006) Managing uncertainty in major equipment procurement in engineering projects, European Journal of Operational Research, Volume 171, Issue 1, 16 May 2006, Pages 123-134
7. Klemetti, A. (2006). Risk management in construction project networks. Helsinki University of Technology, Finland.
8. Hadyan Fahad Al-Ajmi, Emmanuel Makinde (2018). Risk Management in Construction Projects, Journal of Advanced Management Science Vol. 6, No. 2
9. Johnson, M.E., (2001), Learning from toys: lessons in managing supply chain risk from the toy industry, California Management Review.

10. Kleindorfer, P.R., Saad, G.H., (2005), Managing disruption risks in supply chains, Production and Operations Management.
11. Cameron, K.S. and Quinn, R.E. (2006) Diagnosing and Changing Organisational Culture Based on Competing Values Framework
12. Chopra, S., Sodhi, M.S., (2004), Managing risk to avoid supply-chain breakdown, MIT Sloan Management Review.
13. Bhatt and Prof. J. J. Bhavsar and Patel Kishan, Dr. Rajiv in "A Study of Risk Factors Affecting Building Construction Projects' International Journal of Engineering Research & Technology (IJERT), Volume 03, Issue 12 (December 2014)
14. Surabhi Mishra and B Rajesh Mishra in (2016)"A Study on Risk Factors Involved in the Construction Projects" International Journal of Innovative Research in Science, Engineering and Technology Vol. 5, Issue 2, February 2016
15. Gordon, C. M. (1994), Choosing appropriate construction contracting method, Journal of Construction Engineering and Management.
16. Shuaibu Saminu, Raj Prasad and V. Thamilarasu A Study of Various Factors Affecting Risk Management Techniques In Construction Project: A Case Study Of India, International Journal Of Research In Engineering And Technology volume: 04 issue: 03 Mar-2015,
17. R A Bahamid, S I Doh, M A Al-Sharafi and A R Rahimi (2019), "Risk Factors Influencing the Construction Projects in Yemen from Expert's Perspective" IOP Conf. Series: Materials Science and Engineering, 1-7.
18. Krishnakant Upadhyaya, Debasis Mallik (2013) "Analyzing e-Learning as Socio-technical Systems to Understand the Factors Influencing its Effectiveness" Business and Research Perspective, SIMSR, Mumbai, Vol 2, Issue 1, July 2013
19. Hamzaoui et al. (2019) Risk management in construction projects by coupling the SMACC agent with the MADS MOSAR method – application to the dam project in Mascara, Algeria, International Journal of Construction Management,
20. Tsung-Chieh Tsai & Min-Lan Yang (2009) "Risk Management in the Construction Phase of Building Projects in Taiwan" Journal of Asian Architecture and Building Engineering, 8(1), 143-150.
21. Indrajit Roy (2011) "Estimating Value at Risk (VaR) using Filtered Historical Simulation in the Indian capital market" Reserve Bank of India Occasional Papers Vol. 32, No. 2, Monsoon
22. Mahmoudi, A., Abbasi, M., Deng, X., Ikram, M., & Yeganeh, S. (2020). A novel model for risk management of outsourced construction projects using decision-making methods: a case study. Grey Systems: Theory and Application.

23. Zhang, Xueqing, and Saeed Reza Mohandes. "Occupational Health and Safety in green building construction projects: A holistic Z-numbers-based risk management framework." Journal of Cleaner Production 275 (2020): 122788.
24. Qammaz, Amani SAS Bu, and Rufaidah Y. AlMaian. "A critical success factors model for effective implementation of risk management process in the construction projects." Journal of Engineering Research 8, no. 3 (2020).
25. Enshassi, Mohammed SA, Scott Walbridge, Jeffrey S. West, and Carl T. Haas. "Integrated risk management framework for tolerance-based mitigation strategy decision support in modular construction projects." Journal of Management in Engineering 35, no. 4 (2019): 05019004.
26. Chatterjee, Kajal, Edmundas Kazimieras Zavadskas, Jolanta Tamošaitienė, Krishnendu Adhikary, and Samarjit Kar. "A hybrid MCDM technique for risk management in construction projects." Symmetry 10, no. 2 (2018): 46.
27. Mhetre, Krantikumar, B. A. Konnur, and Amarsinh B. Landage. "Risk management in construction industry." Int. J. Eng. Res 5 (2016): 153-155.
28. Wang, T., Gao, S., Li, X. and Ning, X., 2018. A meta-network-based risk evaluation and control method for industrialized building construction projects. Journal of Cleaner Production, 205, pp.552-564.

10. List of Publication

1. Senthil J, Muthukannan, M, “Prediction of Climate Risk Management in Infrastructure Projects”, International Journal of Innovative Technology and Exploring Engineering, 2019, 8(11 Special issue 2), pp. 268–272 DOI: 10.35940/ijitee.K1041.09811S219
2. Senthil J, Muthukannan, M,” Predication of Construction Risk Management in Modified Historical Simulation Statistical Methods” Ecological Informatics, 2021, 66, 101439, https://doi.org/10.1016/j.ecoinf.2021.101439
3. Senthil J, Muthukannan, M, ‘” MSCA based Deep Recurrent Neural Network for Statistics Risk Management in Construction Projects” Acta Montanistica Slovaca. 2021, Vol. 26 Issue 3, p481-497. 17p https://doi.org/10.46544/AMS.v26i3.08
4. Senthil J, Muthukannan, M, “Development of Lean Construction Supply Chain Risk Management Based on Enhanced Neural Network” Materials Today: Proceedings Volume 56, Part 4, 2022, Pages 1752-1757 https://doi.org/10.1016/j.matpr.2021.10.456
5. Senthil J, Muthukannan, M, “Statistical Risk Management in Construction Industry” AIP Conference Proceedings 2463, 020023 (2022) https://doi.org/10.1063/5.0080239